

# IMPACT OF NATURALISTIC DECISION SUPPORT ON TACTICAL SITUATION AWARENESS

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A prototype decision support system (DSS) was developed to enhance Navy tactical decision making based on naturalistic decision processes. Displays were developed to support critical decision making tasks through recognition-primed and explanation-based reasoning processes and cognitive analysis of the decision making problems faced by Navy tactical officers in a shipboard Combat Information Center. Baseline testing in high intensity, ambiguous scenarios indicated that experienced decision makers were not well served by current systems, and their performance revealed periodic loss of situation awareness. A study is described with eight, expert Navy tactical decision making teams that used either their current system alone or in conjunction with the prototype DSS. When the teams had the prototype DSS available, we observed significantly fewer communications to clarify the tactical situation, significantly more critical contacts identified early in the scenario, and a significantly greater number of defensive actions taken against imminent threats. These findings suggest that the prototype DSS enhanced the commanders' awareness of the tactical situation, which in turn contributed to greater confidence, lower workload, and more effective performance.

## INTRODUCTION

Efforts to develop a prototype decision support system (DSS) were initiated as one thrust of the Navy's Tactical Decision Making Under Stress (TADMUS) project. The objective of this effort is to evaluate and demonstrate display concepts derived from current cognitive theory with expert decision makers in an appropriate test environment. The focus of the DSS was on enhancing the performance of tactical decision makers (viz., the Commanding Officer (CO) and Tactical Action Officer (TAO) working as a team) for single ship, air defense missions in high density, ambiguous littoral warfare situations. The approach taken in designing the DSS was to analyze the cognitive tasks performed by the decision makers in a shipboard Combat Information Center (CIC) and then to develop a set of displays to support these tasks based on the underlying decision making processes naturally used by the CO/TAO team.

Cognitive task analyses identified two higher order tasks performed by the CO/TAO team: situation assessment and selection of alternative courses of action (Kaempf, Wolf, & Miller, 1993). The analyses indicated that 87% of the information transactions associated with situation assessment involved feature matching strategies (trying to match the observed events in the scenario to those previously experienced), while 12% of their actions were related to story generation strategies (developing a novel hypothetical explanation to explain the observed events). With regard to selecting courses of action, command level decision makers relied almost exclusively on recognition of applicable tactics based on rules of engagement (94%), while much more rarely developed a general selection strategy extrapolated from previous experience (6% of actions selected).

Baseline tests in representative littoral scenarios corroborated these analyses (Hutchins & Kowalski, 1993; Hutchins, Morrison, & Kelly, 1996). The communications analysis indicated a predominance of feature matching strategies in assessing the situation typically followed by the selection among preplanned response sets (tactics) that were considered to fit the situation. These tests also suggested that experienced decision makers were not particularly well served by current systems in demanding missions. Teams exhibited periodic losses of situation awareness, often linked with limitations in human memory and shared attention capacity. Environmental stressors such as time compression and highly ambiguous information increased decision biases, e.g. confirmation bias, hypervigilance, task fixation, etc. Problems associated with short term memory limitations included: (a) mixing up track numbers (track being recalled as 7003 vs. 7033) and forgetting track numbers; (b) mixing up track kinematic data (track recalled as descending vs. ascending in altitude, closing vs. opening in range, etc.) and forgetting track kinematic data; and (c) associating past track related events/actions with the wrong track and associating completed own-ship actions with the wrong track. Problems related to decision biases included: (a) carrying initial threat assessment throughout the scenario regardless of new information (framing error) and (b) assessing a track based on information other than that associated with the track, e.g., old intelligence data, assessments of similar tracks, outcomes of unrelated events, past decision maker experiences, etc. (e.g. confirmation bias).

## DECISION SUPPORT SYSTEM DESIGN

Based on these analyses, a prototype DSS was developed with the objectives of: (1) minimizing the mismatches between cognitive processes and the information available in the CIC to facilitate decision making; (2) mitigating the short-

comings of current CIC displays in imposing high information processing demands and exceeding the limitations of human memory; and (3) transferring the data in the current CIC from numeric to graphical representations wherever appropriate to facilitate the interpretation of spatial data. It was determined that the DSS should not filter or extensively process data; i.e., it should support rather than aid (automate) decision making and leave as much decision making with the decision makers as possible. The design goal of the DSS was to take the data in the system and present it as meaningful information relative to the decision making tasks being performed based on a theoretical understanding of human decision making.

The current generation DSS was designed expressly for the evaluation of display elements to support feature matching, story generation (viz. Explanation-Based Reasoning (EBR)), and Recognition-Primed Decision making (RPD) with the goal of reducing errors, reducing workload, and improving adherence to rules of engagement. The design was significantly influenced by inputs from subject matter experts to ensure its validity and usefulness for the operational community. It is implemented on a Macintosh computer which may operate independent of, synchronized with, or linked to a scenario driver simulation.

Figure 1 shows the first DSS prototype display. The DSS is a composite of several display modules, which are arranged in a tiled format so that no significant data are obscured by overlapping windows. The DSS was conceived as a supplementary display to complement the existing geo-plot and text displays in current CICs. DSS modules have been discussed and demonstrated in detail elsewhere (cf. Moore, Quinn, & Morrison, 1996). Nevertheless, three modules will be discussed here as an illustration of how the information requirements of tactical decision making tasks were mapped with cognitive processes described in naturalistic decision making theory to generate the DSS.

#### *Track Profile*

The track profile module consists of two graphical displays in the upper portion of the DSS that show the current position of a selected track in both horizontal and plan-form displays. Information requirements addressed by this module included the need to: (1) see where the target track is relative to own-ship, (2) see what the track has been doing over time, (3) recognize whether the target can shoot you, and (4) recognize whether you could shoot the target. An important aspect of this display is that it shows a historical plot of what the target has done in space and time since it was first acquired by the system (the history is replayed each time the target is selected). This greatly offloads the short term memory requirements on the CO and TAO in interpreting the significance of

the selected target. This historical dimension of the display allows the decision maker to see what the track has done and primes his recognition of a likely mission for that track which would account for its actions. In addition, the profiles show own-ship weapon and target threat envelopes displayed in terms of range and altitude so that the decision maker can visualize and compare mental models (templates) as he considers possible track intentions and own ship options.

#### *Response Manager*

The response manager is located immediately below the track profile and is tied to it via a line indicating the target's current distance from own ship. It represents a Gantt chart type display showing a template of pre-planned actions and the optimal windows in which to perform them. The display serves as a graphical embodiment of battle orders and doctrine, and shows which actions have been taken with regard to the selected track. The display is intended to support RPD and serves the need to: (1) recall the relevant tactics and strategies for the type of target being assessed, (2) recognize which actions need to be taken with the target and when they should be taken, and (3) remember which actions have been taken and have yet to be taken for the selected target.

#### *Basis for Assessment*

This module is located in the lower left area of the DSS and is intended to support EBR (story generation). The basis for assessment module presents the underlying data used to generate the DSS's threat assessment for the displayed track. The display shows three categories of assessment decision makers focus on: potential threat, non-threat, or unknown. The decision maker selects the hypothesis he wishes to explore and data are presented in a tabular format within three categories: supporting evidence, counter evidence, and assumptions. These categories were found to be at the core of all story generation in which commanders engage while deciding whether a target with the potential to be a threat is, in fact, a real threat. This EBR related to threat assessment is also typically one of the decision making tasks performed when deciding whether to fire on a target or not. The display was designed to present the relevant data necessary for a commander to consider and evaluate all likely explanations for what a target may be, and what it may be doing (i.e., "intents") through the generation of alternative stories to explain the available and missing data regarding the target in question. The display is also intended to highlight data discrepant with a given hypothesis to minimize confirmation and framing biases. Assumptions listed are those assumptions necessary to "buy into" the selected assessment. As a result, the basis for assessment module is expected to be particularly effective in helping sort out and avoid "Blue-on-Blue" and "Blue-on-White" engagements.

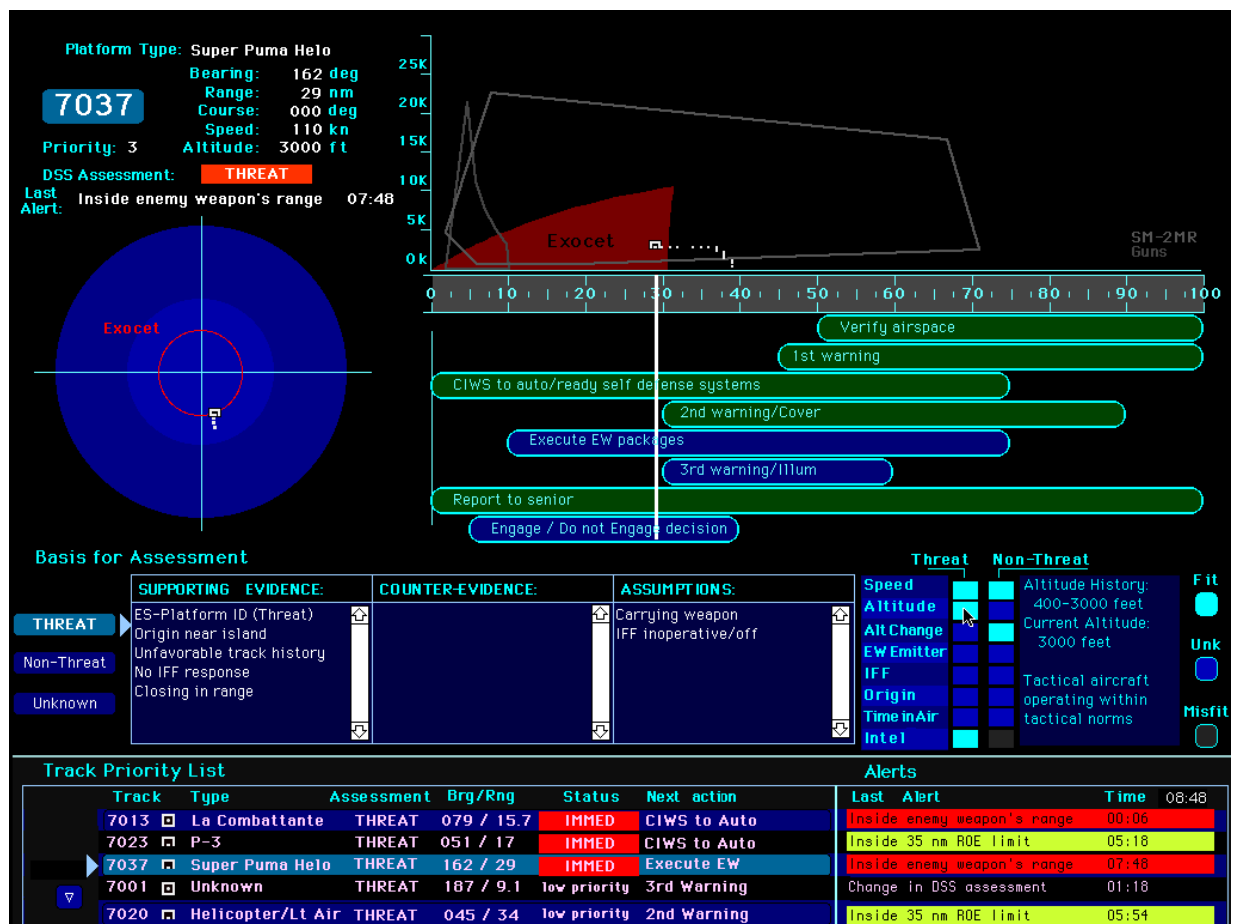


Figure 1. Decision Support System composite display.

## DSS EVALUATION EXPERIMENT

The ultimate goal of any display design is to positively impact the performance of the person-machine system of which it is a part. Therefore, a study was performed to examine how the DSS impacted the decision making of COs and TAOs relative to performance in a traditional CIC in a medium-fidelity simulation. Although the contributions of individual display modules could not be assessed objectively due to resource limitations, overall effects of the DSS on decision performance were examined in terms of a variety of performance criteria.

### Method

Eight expert Navy tactical decision making teams (with emphasis on the CO and TAO) used either their current display systems alone or in conjunction with the prototype DSS at NRAD's *Decision Evaluation Facility for Tactical Teams* (DEFTT) CIC simulator. A within-subject factorial design was employed across four test scenarios such that each team performed two scenarios with the DSS and two scenarios without it. Scenarios were constructed to simulate peace keeping missions with a very high number of targets to be dealt with in a short period of time (i.e. were time compressed), and with a significant number of highly ambiguous

tracks regarding assessment and intent. Subjects were given appropriate geo-political and intelligence briefings prior to each test run. The order of the scenarios and DSS conditions was counterbalanced using a Latin Square. Criterion-referenced training with the baseline DEFTT display system and with the DSS was provided, and two practice scenarios were run prior to beginning the test session. In addition to collecting objective data on tactical actions, display usage, control inputs, and voice communications, subjective assessments (via questionnaires and a structured interview) were solicited from each CO and TAO at the conclusion of the test session.

### Results

Results indicated no evidence of a practice effect over the four-scenario test session and no consistent differences between the scenarios themselves. Substantial differences were observed, however, between teams – notably in their subjective workload assessments and in their communications.

The results of primary interest concerned the extent to which the DSS promoted greater awareness of the tactical situation by the CO and TAO. Awareness of the tactical situation was examined via several performance measures. Specifici-

cally, it was predicted that if the CO/TAO team was more aware of the tactical situation, they would:

- identify the critical contacts earlier and more accurately;
- take more of the tactical actions required by the rules of engagement in a timely manner (i.e., later); and
- ask fewer questions to clarify previously reported track data and the relative locations of tracks.

**Critical contacts.** During the scenario runs, the experimenter probed the CO/TAO team at prespecified times to identify the tracks that were considered to be of greatest tactical interest at that time. Their responses were contrasted with those of an independent group of five subject matter experts. As shown in Figure 2, significantly more of the critical contacts were identified when the DSS was available. Significant differences ( $p < .05$ ) were noted at both the early and mid-scenario probes; performance was comparable at the late probe, however. Late in the scenario the critical tracks may become more obvious even without the DSS. Nevertheless, earlier recognition of critical tracks earlier in the scenario affords decision makers a broader array of response options and permits more effective coordination of response actions.

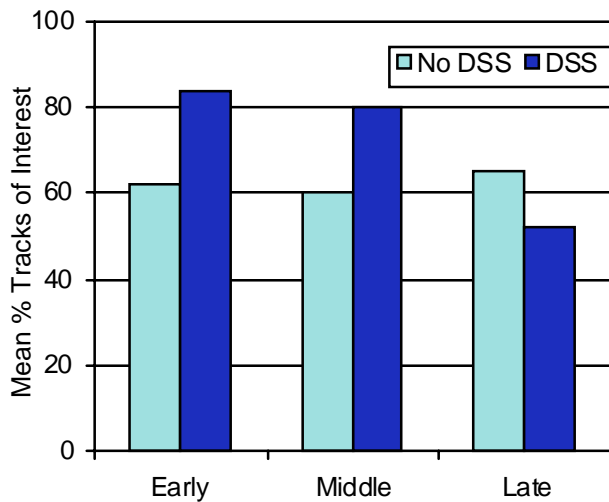


Figure 2. Percent of critical contacts reported as tracks of interest.

**Tactical actions.** Using the rules of engagement as a benchmark for decision performance in the scenarios, a group of subject matter experts assessed whether the CO/TAO teams warned and/or illuminated threat tracks at specified times and took appropriate defensive actions. A modified form of the AAW Team Performance Index (Dwyer, 1992) was used for scoring tactical performance, and these data are summarized in Figure 3. In scenarios when the DSS was available, CO/TAO teams were significantly more likely to take defensive actions in a timely manner against imminent threats ( $p < .05$ ). This indicates that the DSS promoted an earlier recognition of the emerging risks of the tactical situation. By contrast, no difference was observed in the number of tracks that were warned or illuminated when the DSS was available. However, several

subject matter experts contended that these may not be diagnostic performance indices since they represent provocative tactical actions that commanders may consider to be inappropriate against certain tracks in a littoral situation. Not taking provocative actions would be appropriate and expected if commanders had assessed that the track was not an imminent threat, and felt comfortable with prolonging those actions because they had a good tactical picture - as would be expected if the DSS was being effective in meeting its design objectives.

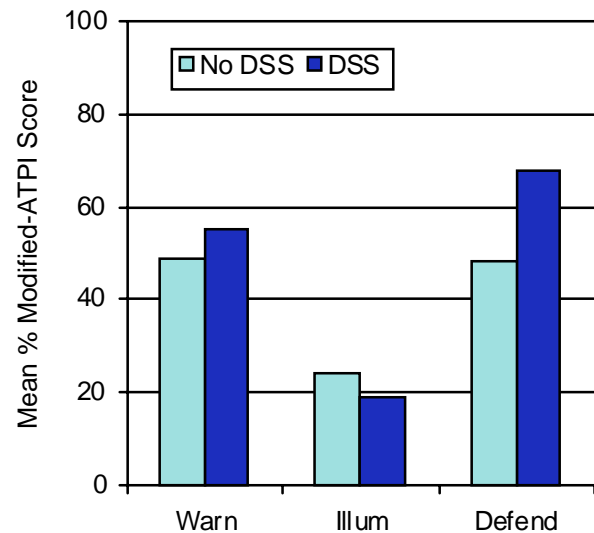


Figure 3. Team performance of tactical actions required by the rules of engagement.

**Clarifying communications.** The voice communications during each of the scenario runs were coded by their message content (exchanging tactical data or track status, correlating or assessing tracks and issuing orders, and clarifying the tactical situation). Overall, about 20% of the communications were for clarification purposes, reflecting uncertainty about track location, kinematics, identification, status, or priority. When the teams had the DSS available, fewer communications were aimed at clarifying the tactical situation, particularly track kinematics, identification, and priority - each of which are directly aided by the DSS. On the other hand, with the DSS, decision makers tended to spend more time clarifying ambiguous communications and checking on the status of actions. While this result may seem counterintuitive, it reveals a greater situation awareness where ambiguous, incomplete, or erroneous communications are more likely to be caught and corrected when the DSS was available.

**User responses.** Feedback from the expert CO/TAO teams who participated in this experiment also indicated that the DSS provided them an excellent summary of the overall tactical situation as well as of key data for individual tracks. In particular, COs and TAOs considered that both the Track Profile and the Basis for Assessment modules provided important information not readily available in present day systems (see Figure 4). Since the Track Profile module supported feature matching, which is the most commonly used decision strategy, its high rating was anticipated. Yet, when the track

data are conflicting or ambiguous and when the decision maker has time available, the Basis for Assessment module was rated as helping substantially. Note that by encouraging decision makers to consider the full range of available evidence along with various explanations for it, this module reduces the likelihood of mistakenly engaging friendly or neutral tracks, and was rated highly with regard to avoiding Blue-on-Blue and Blue-on-White engagements.

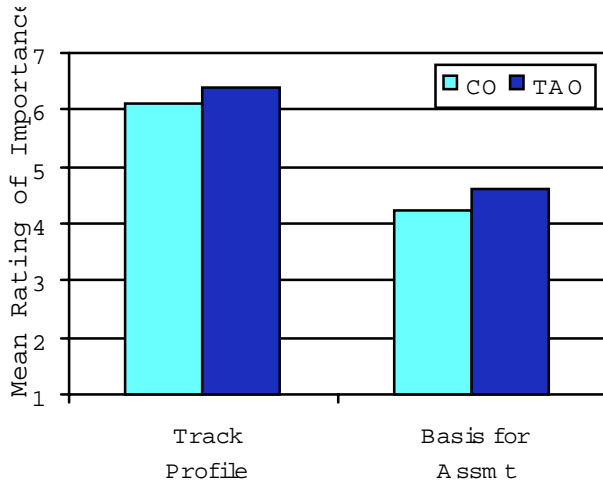


Figure 4. Mean CO and TAO ratings of the importance of information in Track Profile and Basis for Assessment.

### CONCLUSIONS

Operational decision making predominantly relies on feature matching strategies. To a lesser extent when faced with conflicting or ambiguous data, decision makers employ story generation or explanation based reasoning strategies. Displays that are consistent with these naturalistic decision making strategies provide the most useful support to commanders, facilitating the rapid development of an accurate assessment of the situation. Displays that support both feature matching and explanation based reasoning are recommended for complex decision making tasks. While the feature matching displays will likely be used far more often, the explanation based reasoning display is of substantial value under certain circumstances, particularly with less experienced decision makers.

The DSS was developed for application to Navy tactical decision making on a single ship in support of AAW in dense, fast-paced littoral settings. With some adaptation, it could support other military decision situations, including concurrent decisions involving other warfare areas, higher-level, supervisory decisions involving multi-ship battle groups, and even collaboration among tactical decision makers in joint service or multi-national operations. Several new research projects are underway to explore these applications. In addition to these direct applications to support military decision making, the decision support and display principles identified through this effort are relevant to other complex decision making settings, such as nuclear power control, flight control, process control, and disaster relief planning. Further, additional work

is looking at developing derivative displays reflect emerging theories of decision making, extension of the DSS concepts to other workstations within the CIC, as well as better integration of DSS modules with shipboard data processing systems.

### ACKNOWLEDGMENTS

This effort was performed as part of the Tactical Decision Making Under Stress (TADMUS) project, sponsored by the Office of Naval Research, Cognitive and Neural Science Technology Division with Gerald S. Malecki as program manager. The authors gratefully acknowledge the substantial contributions of Jeffrey Grossman, Steve Francis, Brent Hardy, Pat Kelly, C. C. Johnson, Ron Moore, Connie O'Leary, Mike Quinn, Will Rogers, and Dan Westra to various phases of this project, as well as our colleagues at NAWC-TSD. We acknowledge the support of the TADMUS Technical Advisory Board, and dedicate this paper to the memory of Dr. Martin A. Tolcott, its Chair from 1988 through 1996.

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